

## SPECIFICATION

## SILVER ALLOY FOR USE IN REFLECTION FILMS

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## TECHNICAL FIELD

The present invention relates to a silver alloy suitable as a constituent material for a reflection film to be provided in an optical recording medium, display or the like, and especially to a silver alloy for a reflection film, which is capable of maintaining reflectivity during a long-term service.

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## BACKGROUND ART

Silver is said to be the most preferable material for a reflection film being used in an optical recording medium, display or the like. The reason is that silver, in addition to a high reflectivity, is less expensive than gold which also has a high reflectivity. Especially, in the field of optical recording media, application of materials having higher reflectivity has been demanded as the field makes the transition to recordable and rewritable media such as CD-R/RW and DVD-R/RW/RAM. This is ascribable to a cause that organic dye materials have been widely used as a constituent material for a recording layer in recordable and rewritable media, and organic dye materials lead to a greater attenuation of laser, so that the attenuation should be complemented by improving the reflectivity of a reflection film.

In contrast, silver is poor in corrosion resistance, thereby has a drawback that corrosion changes the color of silver into black and will deteriorate the reflectivity. One of the factors contributing a corrosion of a reflection film is that for example the film has a poor corrosion resistance to an organic dye material which is applied to a recording layer in an optical recording medium although it varies according to equipment on which the film.

is applied, and as a result deterioration in reflectivity can be recognized after a long-term use. A reflection film in a display is likely to be corroded due to moisture or the like in the atmosphere.

There is further an issue of deterioration in reflectivity to a reflection  
5 film comprising silver caused by heat. Although it is not known exactly how heat deteriorates a reflectivity, a phenomenon has been confirmed that when a silver thin film is heated, the thin film gets local coagulation and exposes its substrate layer. Therefore, heat resistance is also required to a reflection film used for an optical recording media, plasma display or the like because the  
10 film is subjected to heat.

In order to address the above-discussed issue of deterioration in a reflectivity of a reflection film, developments of a silver alloy for use in a reflection film have been conventionally carried out in which both corrosion resistance and heat resistance are increased while a reflectivity is insured.  
15 Many of the reflection films have silver as a main component and are added by one or two or more various additive elements. For instance, it is disclosed 0.5-4.9atm% of palladium has been added to silver. These silver alloys are said to have a good corrosion resistance, can maintain reflectivity under an environment of service, thereby being suitable as a reflection film. Refer to  
20 Patent Document 1 for details of the earlier technology.

Patent Document 1: Japanese Patent Application Laid-open No. 2000-109943

With respect to the above-discussed silver alloys, some tentative improvements are recognized in terms of corrosion resistance and heat resistance. However, there is no guarantee that these silver alloys do not  
25 deteriorate at all under an environment of service. There is also no guarantee against deterioration in reflectivity, and so that materials capable of maintaining a higher level of reflectivity have been demanded.

In the field of optical recorders, red semiconductor laser (wavelength of 650nm) is currently applied as a light source for recording, however practical use of blue laser (wavelength of 405nm) has been in sight recently. Application of blue laser can insure a five- or six-fold storage capacity compared to the present optical recorders, so that it is considered blue laser-applied optical recorders will become mainstream in the next-generation ones. In this regard, the present inventors have confirmed the reflectivity of a reflection film will fluctuate in accordance with the wavelength of laser to be irradiated, and especially have confirmed irradiation of laser having a short-wavelength will cause deterioration in reflectivity irrespective of presence or absence of corrosion and the deterioration in reflectivity due to corrosion will be more substantial in degree than in a case of irradiation of laser having a long-wavelength. Thus, in order to manufacture recording media capable of addressing the future development of light sources for recording, it is desired a development of materials having a higher reflectivity with respect to irradiation of laser of short-wavelength band and further capable of maintaining reflectivity within a practical scope of use.

The present invention has been made against the above background, and relates to a silver alloy composing a reflection film in an optical recording medium or the like. It is an objective of the invention to provide a material capable of serving with the reflectivity kept not deteriorated due to a long-term use. Furthermore, the present invention provides a material having a higher reflectivity with respect to laser beams of short-wavelength.

## DISCLOSURE OF THE INVENTION

In order to solve the problems, the present inventors made a selection of preferable additive elements with silver centered on similarly to the earlier technologies. As a result thereof, the present inventors found metal elements

having lower melting point than that of silver have an effect of maintaining reflectivity when added as an additive element and are useful in improving heat resistance, moisture resistance, or sulfur resistance, thereby came up with the present invention.

5           The present invention is drawn to a silver alloy for use in a reflection film in an optical recording medium, comprising silver as a main component, and at least one metal element as a first additive element having lower melting point than that of silver.

          Selection of metallic elements as a first additive element having a  
10   melting point lower than silver depends on which properties of a thin film should be given weight to. To the best of the present inventors' knowledge, low-melting metallic elements useful in improving the properties of a thin film comprising silver are aluminum, indium, tin, bismuth, gallium, zinc, strontium, calcium and germanium, and out of these elements, aluminum, indium and tin  
15   are especially useful in improving a sulfur resistance of a thin film. On the other hand, bismuth, gallium, zinc, strontium, calcium and germanium are useful in improving heat resistance and moisture resistance. Therefore, inclusion of at least one of these metallic elements allows a silver thin film to have high reflectivity.

20           The present inventors' study confirmed a silver alloy added with gallium among the low-melting metallic elements raised above as a first additive elements contributes to maintaining especially a higher level of properties required for a reflection film. The silver-gallium alloy is preferable not only to a reflection layer for an optical recording medium but also to a  
25   reflection film for a display.

          Further in the present invention, it is preferable if at least one of elements comprising platinum, gold, rhodium, iridium, ruthenium, palladium, lead, copper, manganese, silicon, nickel, chrome, cobalt, yttrium, iron;

scandium, zirconium, titanium, niobium, molybdenum, tantalum, tungsten, hafnium, lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, thulium, ytterbium, magnesium, and boron is added as a second additive element. These  
5 elements act multiply with the first additive elements to improve sulfur resistance, moisture resistance, and heat resistance.

Especially, a silver alloy added with, as a second additive elements, platinum, palladium, thulium, or dysprosium is a preferable alloy, which can effectively inhibit coagulation, which will generate in a thin film material in  
10 an humidified environment.

A concentration of the additive elements, namely a total of the concentration of the first and second additive elements is preferable if it is adjusted to 0.01-5.0 atomic %. The reason is that an added amount of less than 0.01 atomic % will have no effect of maintaining reflectivity, and a  
15 concentration of the additive elements exceeding 5.0 atomic % will deteriorate the reflectivity significantly in some environment and wavelength of incident laser beam, thereby guaranteeing quality reflectivity. A preferable concentration in particular is 0.01-1.5 atomic % because reflectivity of higher level can be maintained irrespective of environment and wavelength of  
20 incident laser beam.

The silver alloy as a material for a reflection film according to the present invention as discussed above can be produced through a melting casting process or sintering process. There is no specifically difficult point in producing the silver alloy through a melting casting process, and it can be  
25 produced through a commonly used process where each raw material is checkweighed, melt, mixed, and cast. There is also no specifically difficult point in producing the silver alloy through a sintering process, and it can be

produced through a commonly used process where each raw material is checkweighed and sintered.

The silver alloy according to the present invention has preferable properties for reflection films, and is inhibited from deterioration in reflectivity in a working process. Further as will be discussed later, the silver alloy shows better and sustainable reflectivity compared with the conventional materials for reflection films under irradiation of a short-wavelength laser beam. As discussed above, a sputtering process has been generally applied in producing reflection films for optical recording media. Therefore, the sputtering process comprising the silver alloy according to the present invention can produce optical recording media, displays or the like provided with reflection films having preferable properties.

As discussed above, the present invention can produce reflection films with less deterioration in reflectivity after a long-term use, thereby prolonging durability of various equipment such as optical recording media, displays or the like to which reflection films are applied. Further, the silver alloy according to the present invention shows better and sustainable reflectivity compared with the conventional materials for reflection films under irradiation of a short-wavelength laser beam. Thus, the present silver alloy can be applied to recording media for optical recorders using a short-wavelength laser as a light source, which are expected to take root in the future.

#### BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, a preferred example of the present invention will be described together with a comparative example. In the example, various silver alloys of binary and ternary compositions having silver as a main component were produced, with which targets were produced, and thin films were formed through a sputtering method. Thus formed thin film were

subjected to corrosion tests (acceleration tests) under various environments for studying variations in reflectivity of post corrosion tests.

In producing a silver alloy, each metal was checkweighed to reach a predetermined concentration, was molten in a high-frequency melting furnace  
5 and mixed to prepare an alloy. Then, it was poured into a mold to solidify for preparing an ingot, which was forged, rolled, heat treated, and formed to produce a sputtering target.

In producing a thin film, a substrate (borosilicate glass) and a target were placed in a sputtering apparatus. After a vacuum was drawn in the  
10 apparatus to a level of  $5.0 \times 10^{-3}$  Pa, argon gas was introduced to a level of  $5.0 \times 10^{-1}$  Pa. A film was formed under sputtering conditions with 4kW of direct-current and time period of 8 seconds to make the film thickness 1200Å. Film thickness distribution was confirmed within  $\pm 10\%$ .

Thus produced thin film was first evaluated in terms of heat resistance  
15 and moisture resistance. Evaluation of these properties was done with the thin film exposed to an environment and with the reflectivity of a tested thin film measured while a wavelength was changed with the use of a spectrophotometer, and variation in reflectivity was inspected with the reflectivity in each wavelength of the silver of immediately after film  
20 formation standardized.

In a heat test for inspecting a heat resistance of the thin film, the thin film was placed on a hot plate, heated for 1 hour at 250°C in the atmosphere, and evaluated in terms of reflectivity after heating. In humidification tests for inspecting a moisture resistance of the thin film, the thin film was exposed  
25 in the atmosphere having the temperature of 100°C and the humidity of 100%, and evaluated in terms of reflectivity after humidifying. The humidification tests were carried out in two ways: one with an exposure time of 24 hours (Humidification Test I); and the other with an exposure time of 100 hours

(Humidification Test II). Results of the corrosion tests are shown in Tables 1-3. The reflectivity values as shown in the tables are relative values to those of the silver of immediately after film formation being set as 100. Each measured value represents reflectivity in the wavelengths of 400nm, 560nm, and 650nm (corresponding to the wavelength of blue, yellow, and red laser, respectively). For comparison, the tables further show test results on a thin film, which was made with the use of the target composed of pure silver.

**Table 1**

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Wavelength of incident light: 400nm

Sample composition (at%)	Reflectivity			
	Immediately after deposition	Heat test	Humidification test I	Humidification test II
Ag-3.9Al	80.6	52.1	68.0	68.1
Ag-0.9In	92.4	62.3	63.2	52.8
Ag-0.9Sn	88.5	80.6	58.5	31.4
Ag-1.4Sr	90.8	84.1	86.4	81.6
Ag-2.6Ca	87.1	61.6	80.8	77.2
Ag-0.5Al-0.5In	97.9	56.1	90.6	89.9
Ag-0.5In-0.4Sm	104.3	91.1	80.7	35.7
Ag-0.5In-0.8Cu	101.1	89.9	87.4	70.7
Ag-0.5In-0.5Bi	94.4	71.4	80.4	51.6
Ag-0.5In-0.5Ge	94.7	90.1	88.1	84.0
Ag-0.5Sn-0.4Cu	92.1	89.1	79.5	63.2
Ag (Comparison)	100.0	30.5	45.9	37.5



Table 2

Wavelength of incident light: 550nm

Sample composition (at%)	Reflectivity			
	Immediately after deposition	Heat test	Humidification test I	Humidification test II
Ag-3.9Al	90.4	68.7	90.1	93.2
Ag-0.9In	96.5	76.0	85.3	76.2
Ag-0.9Sn	97.7	93.8	88.3	69.3
Ag-1.4Sr	99.4	94.7	97.6	96.2
Ag-2.6Ca	98.2	82.5	97.4	92.7
Ag-0.5Al-0.5In	98.8	73.8	95.0	95.6
Ag-0.5In-0.4Sm	99.7	92.8	85.8	69.7
Ag-0.5In-0.8Cu	100.0	92.8	85.8	69.7
Ag-0.5In-0.5Bi	98.9	80.6	89.3	62.0
Ag-0.5In-0.5Ge	97.3	95.1	92.5	89.4
Ag-0.5Sn-0.4Cu	98.7	97.7	89.1	75.1
Ag (Comparison)	100.0	52.5	78.4	67.8

5 Table 3

Wavelength of incident light: 650nm

Sample composition (at%)	Reflectivity			
	Immediately after deposition	Heat test	Humidification test I	Humidification test II
Ag-3.9Al	95.2	84.3	95.4	95.1
Ag-0.9In	97.4	79.6	85.8	81.0
Ag-0.9Sn	98.7	96.2	93.1	80.5
Ag-1.4Sr	100.0	95.9	98.1	96.6
Ag-2.6Ca	98.5	88.2	98.1	93.3
Ag-0.5Al-0.5In	98.8	76.0	95.6	96.1
Ag-0.5In-0.4Sm	99.1	92.9	86.8	42.0
Ag-0.5In-0.8Cu	99.9	92.3	86.0	71.3
Ag-0.5In-0.5Bi	99.3	81.5	89.9	63.7
Ag-0.5In-0.5Ge	98.3	97.0	95.0	92.4
Ag-0.5Sn-0.4Cu	99.3	98.6	89.3	75.4
Ag (Comparison)	100.0	60.5	86.0	78.6

It is known from the above results that the thin film produced with the silver alloy according to the present Example shows higher values than those

of silver in terms of reflectivity, and improvement effect in heat resistance and moisture resistance was confirmed. As a general tendency, it is perceived the shorter a wavelength of incident light is, the lower the reflectivity becomes.

Next, targets comprising various silver alloys to which gallium had been  
5 added as a first additive element were produced, silver-alloy thin films  
(1200Å) were produced, and properties thereof were evaluated. The  
producing process of the targets and sputtering conditions for producing the  
thin films are identical to those described above. In an evaluation, two tests  
were carried out. Specifically, heat tests identical to those as described above  
10 and humidification tests (Humidification test III) in which the thin films are  
exposed in an atmosphere of a temperature of 80°C and a moisture of 85% for  
24 hours were carried out. Tables 4-6 show results of the tests.

**Table 4**

Wavelength of incident light: 400nm

Sample composition (at%)	Reflectivity		
	Immediately after deposition	Heat test	Humidification test III
Ag-3.6Ga	98.0	44.1	98.1
Ag-0.5Ga	95.6	51.5	96.3
Ag-0.8Ga	95.3	69.8	96.1
Ag-1.5Ga	91.0	84.2	91.0
Ag-2.0Ga	85.4	79.0	81.5
Ag-0.8Ga-0.5Zn	83.2	75.8	76.9
Ag-0.2Ga-0.2Cu	94.7	63.6	80.6
Ag-0.5Ga-0.3Cu	90.1	78.9	88.2
Ag-1.0Ga-0.5Cu	88.3	63.7	81.4
Ag-0.25Ga-0.25Sn	88.9	76.1	81.5
Ag-0.5Ga-0.5Sn	90.4	77.6	88.6
Ag-0.2Ga-0.3Pd	91.1	78.6	90.3
Ag-0.5Ga-0.5Pd	88.6	88.3	83.6
Ag-1.0Ga-0.5Pd	84.7	65.2	87.9
Ag-0.5Ga-0.5In	94.3	79.4	94.0
Ag-0.2Ga-0.2In	93.6	60.9	94.2
Ag-1.2Ga-0.2In	92.4	67.8	91.5
Ag-0.6Ga-0.2In	92.7	67.8	91.1
Ag (Comparison)	100.0	30.5	79.8

Table 5

Wavelength of incident light: 550nm

Sample composition (at%)	Reflectivity		
	Immediately after deposition	Heat test	Humidification test III
Ag-0.3Ga	98.6	67.3	100.3
Ag-0.5Ga	97.7	73.0	99.5
Ag-0.8Ga	98.1	81.8	99.8
Ag-1.5Ga	97.0	94.8	98.5
Ag-2.0Ga	95.8	93.9	96.2
Ag-0.8Ga-0.5Zn	92.8	90.0	85.6
Ag-0.2Ga-0.2Cu	96.9	77.6	96.0
Ag-0.5Ga-0.3Cu	97.2	93.8	88.3
Ag-1.0Ga-0.5Cu	94.6	82.6	91.8
Ag-0.25Ga-0.25Sn	97.7	94.6	96.9
Ag-0.5Ga-0.5Sn	97.3	95.0	98.2
Ag-0.2Ga-0.3Pd	98.1	95.6	94.1
Ag-0.5Ga-0.5Pd	97.0	91.4	94.3
Ag-1.0Ga-0.5Pd	93.8	85.8	99.3
Ag-0.5Ga-0.5In	97.5	88.9	98.7
Ag-0.2Ga-0.2In	97.8	72.6	99.1
Ag-1.2Ga-0.2In	95.6	90.6	93.9
Ag-0.6Ga-0.2In	97.6	83.8	98.2
Ag (Comparison)	100.0	52.5	92.3

Table 6

Wavelength of incident light: 650nm

Sample composition (at%)	Reflectivity		
	Immediately after deposition	Heat test	Humidification test III
Ag-0.3Ga	98.8	76.9	100.6
Ag-0.5Ga	98.1	80.9	99.8
Ag-0.8Ga	98.4	85.6	100.2
Ag-1.5Ga	97.7	96.3	99.2
Ag-2.0Ga	96.7	95.8	97.9
Ag-0.8Ga-0.5Zn	95.5	93.6	96.6
Ag-0.2Ga-0.2Cu	99.2	80.4	84.6
Ag-0.5Ga-0.3Cu	97.9	94.8	97.8
Ag-1.0Ga-0.5Cu	95.9	90.4	91.3
Ag-0.25Ga-0.25Sn	98.5	92.6	94.1
Ag-0.5Ga-0.5Sn	98.4	95.8	98.3
Ag-0.2Ga-0.3Pd	99.4	95.3	98.0
Ag-0.5Ga-0.5Pd	98.0	91.1	93.9
Ag-1.0Ga-0.5Pd	96.8	92.3	95.2
Ag-0.5Ga-0.5In	97.7	90.3	99.3
Ag-0.2Ga-0.2In	98.2	75.8	99.6
Ag-1.2Ga-0.2In	97.0	95.8	96.5
Ag-0.6Ga-0.2In	97.9	88.0	98.9
Ag (Comparison)	100.0	60.5	94.5

It is known from Tables 4-6 that the silver-alloy thin film to which gallium had been added as a first additive elements were improved in terms of heat resistance and moisture resistance similarly to those as described above. The silver-gallium-based alloys especially have a higher effect of maintaining reflectivity, and show good effect of maintaining reflectivity particularly with respect to incident light of a short wavelength. In this respect, it was confirmed a silver-gallium-based alloy thin film is useful in an application to a reflection film in a display, which demands a uniform reflectivity irrespective of a wavelength of incident light.

Next, sulfur tests were carried out with respect to a part of the thin film produced, in order to evaluate sulfur resistance and reflectivity of post sulfur

tests were evaluated. In the sulfur tests, the thin films were immersed in a sodium sulfide solution of 0.01% having a temperature of 25°C for an hour. The test results are shown in Table 7, from which it was confirmed that the alloy thin film according to the present example has a tendency to improved sulfur resistance in all wavelength bands.

Table 7

Sample composition (at%)	Reflectivity					
	400nm		550nm		650nm	
	Immediately after deposition	After Test	Immediately after deposition	After Test	Immediately after deposition	After Test
Ag-0.9In	92.4	65.0	96.5	81.6	97.4	86.8
Ag-0.9Sn	88.5	36.3	97.7	55.9	98.7	67.4
Ag-3.9Al	80.6	33.3	90.4	51.1	95.2	60.6
Ag-0.2Ga-0.2Cu	94.7	32.0	96.9	45.3	99.2	59.3
Ag-0.5Ga-0.3Cu	90.1	50.4	97.2	63.8	97.9	73.0
Ag-1.0Ga-0.5Cu	88.3	30.0	94.6	64.7	95.9	78.1
Ag-0.2Ga-0.3Pd	91.1	50.0	98.1	65.9	99.4	73.6
Ag-0.5Ga-0.5Pd	88.6	52.8	97.0	74.1	98.0	80.4
Ag-1.0Ga-0.5Pd	84.7	64.0	93.8	78.1	96.8	82.6
Ag-0.5Ga-0.5In	94.3	46.8	97.5	64.6	97.7	75.0
Ag-0.2Ga-0.2In	93.6	28.9	97.8	43.1	98.2	57.6
Ag-1.2Ga-0.2In	92.4	40.0	95.6	62.6	97.0	74.9
Ag-0.6Ga-0.2In	92.7	31.4	97.6	46.6	97.9	60.6
Ag-0.5In-0.4Sm	104.3	52.4	99.7	68.0	99.1	76.7
Ag-0.5In-0.5Cu	101.1	55.6	100.0	74.5	99.9	81.2
Ag-0.5Al-0.5In	97.9	37.3	98.8	50.5	98.8	63.5
Ag-0.5In-0.5Bi	94.4	37.6	98.9	56.8	99.3	69.0
Ag-0.5In-0.5Ge	94.7	47.2	97.3	65.3	98.3	74.9
Ag-0.5Zn-1.7Cu	95.6	38.7	98.1	54.7	98.4	68.1
Ag (Comparison)	100.0	20.2	100.0	25.5	100.0	43.7

Further, DVD-R media were produced with the use of a sputtering target comprising a silver-gallium-base silver alloy produced in the present example, and were evaluated in terms of properties as a reflection film for an optical record medium. In this test, the used as a substrate was a polycarbonate substrate with a diameter of 120mm, a board thickness of

0.6mm, a groove depth of 0.17 $\mu$ m, groove width of 0.3 $\mu$ m, and a groove pitch of 0.74 $\mu$ m, which had been produced with an injection molding machine having a stamper formed with a preformatting-pattern. Then, metal-containing azo-based recording ink was applied onto a top surface of the substrate through a spin coating process, the top surface was dried and subsequently formed with a reflection film having a thickness of 1200Å with the use of a sputtering target as produced in the present example. Then, a polycarbonate substrate having the same size as the substrate was bonded onto the substrate with the use of ultraviolet-curing resin to produce a DVD-R medium.

The produced DVD-R medium was subjected to an optical disk evaluation unit (Optical Disk Evaluation Unit ODU 1000 made by Pulstec Industrial Co., Ltd.) to measure jitter values, PI error (PI8 error), and PO error at an early stage, and measured values were confirmed within the range of DVD standard. After the confirmation, an acceleration environmental test was carried out on the DVD-R medium, in which the medium was exposed in an environment with a temperature of 80°C and with a relative humidity of 85% to measure respective values of the DVD-R medium of post acceleration environmental test with the use of the evaluation unit.

Figs. 1-4 show relationships between humidification time and jitter values, PI error, PI8 error, and PO error. The figures also show results of similar tests carried out on a DVD-R medium having a reflection film of pure silver and on a commercially available DVD-R medium.

As will be understood from the figures, the recording medium having a reflection film comprising a silver-gallium-based silver alloy according to the present example meets the standard in terms of respective values even after long time of humidification, and the medium was confirmed to have long-lasting stability. In contrast, the recording medium having a reflection film

of pure silver became unrecognizable by the recording equipment after humidiation of 150 hours and became nonusable. It was also confirmed that the commercially available DVD-R medium exceeded the standard in terms of jitter values, and is inferior to the DVD-R medium according to the present example in terms of properties although the error values successfully cleared the standard.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows results (jitter values) of an acceleration environmental test carried out on a DVD-R medium having a reflection film according to the present example;

Fig. 2 shows results (PI error values) of an acceleration environmental test carried out on a DVD-R medium having a reflection film according to the present example;

Fig. 3 shows results (PI8 error values) of an acceleration environmental test carried out on a DVD-R medium having a reflection film according to the present example; and

Fig. 4 shows results (PO error values) of an acceleration environmental test carried out on a DVD-R medium having a reflection film according to the present example.